adoption of leadless glazes. That leadless glazes of a high brilliancy, covering power and durability, and adapted to all kinds of table, domestic and sanitary ware, to china furniture, to tiles, insulators and electric fittings of the most varied kind, are perfectly practicable, was illustrated by reference to the numerous examples of leadless glazed ware which, thanks to the liberality of a number of the manufacturers, were exhibited to the audience. Among them were specimens from Mintons, from the Worcester Royal Porcelain Company, Burgess and Leigh, Barker and Read, Bernard Moore, the Crystal Glaze Company, Hawley Brothers, Defries, and others. Telegraph insulators of Doulton's and Buller's make were exhibited by the Post Office.

Dr. Thorpe stated that leadless glazed ware was now being supplied to a number of the Government Departments and to certain of the London Clubs. He further stated that the London School Board had resolved to insert a clause in all specifications for new works strictly prohibiting the use of any pottery goods involving lead glaze wherever practicable.

The fact that the application of leadless glazes has passed beyond the experimental stage is so obvious that the Secretary of State now proposes to relax the Special Rules, issued by the Factory Department, in regard to the pottery industry in the case of factories or processes in which no compounds of lead are used.

Dr. Thorpe concluded by remarking that every intelligent potter must concede that there is an ample field for investigation by modern methods of attack into problems connected even with the first principles of his art. The craft of the potter largely depends upon the intelligent application of scientific principles. Whether, however, modern science enters into it to the extent that might be desired is perhaps open to question.

There is probably no industry in the world, certainly none in England, so conservative in its operations as that of the potter. The best of English earthenware still enjoys, no doubt, the pre-eminence which the skill and aptitude of Wedgwood and his immediate followers imparted to it. The great potter was fully abreast of the physical science of his day, and was quick to test or take advantage of any discovery which seemed to promise to be of service to his art. But perhaps it may be doubted whether the spirit of Wedgwood actuates his successors to the extent that might be desired. It is at least certain that the exercise of this spirit, that is, the intelligent application of simple chemical principles, would years ago have obviated, to a large extent at least, this evil of plumbism among the pottery workers.

APPLICATIONS OF ELECTRICAL SCIENCE.[1]

I FEEL very much honoured by having been placed in the position I now occupy, and by having to deliver this opening address to. the Dublin Branch of the Institution of Electrical Engineers. I believe that we are one of the first branches that has developed into the meeting stage of our existence, and may congratulate ourselves on having passed through our larval transformations safely and rapidly, and on our having been the first to emerge into an imago.

The action of the parent Institution in founding these local branches is worthy of our grateful commendation. We are left perfectly free to develop our own life untrammelled by any rules except such as we would ourselves have necessarily chosen to govern our actions. We have the great advantage of being a branch of a most distinguished Institution of world-wide reputation, and that without paying any extra subscription. I hope that we will add to the life and work of that Institution, and thereby promote both our own interests and the welfare of mankind. Papers and discussions here will be taken as delivered to the Institution of Electrical Engineers, and, if of sufficient merit, will be published in its *Proceedings*, thus securing to us a world-wide publication, while at the same time ensuring that Ireland is credited with the work done.

The history of electricity in the nineteenth century is far too large a subject for an occasion like the present one, but certain aspects of this history convey valuable lessons for the future and may well engage our attention in this last year of the century, and may help us to lay the foundations for further advance in the next. The aspect of the history of electricity during the nineteenth century to which I desire to direct your attention is an object-lesson of how to apply science to further the well-being of mankind. The history of any applied science might be considered in this aspect, but the history of applied electricity is particularly appropriate for being thus considered, for several reasons. The history is condensed within a few years; the discoveries of science have followed one another with extraordinary rapidity, and within a few years after the discoveries were made they have been applied to the use of man. It is just a hundred years since Volta discovered how to make continuous electric currents. Within a few years of that discovery their chemical actions were discovered and electric lights produced, both arc and incandescent. Twenty years afterwards the magnetic effect of an electric current was discovered by Œrsted, its mathematical theory evolved by Ampere, and the law of its intensity worked out by Ohm. Some fifteen years afterwards, Faraday discovered how to produce electric currents by magnetism. Immediately after the discovery of the principle of the conservation of energy it was applied to electro-magnetism, and the foundation of our whole system of electro-magnetic measurement was laid. Faraday's belief in the correlation of electricity and light, following lines suggested by Lord Kelvin, was forged into a consistent theory by Clerk Maxwell, and this theory confirmed experimentally by Hertz. Such, in brief, is the scientific history of electro-magnetism during the expiring century, and on this science practically all the applications of electricity depend.

I may pause for an instant to consider where this theory now lands us. The all-pervading ether has been realised as the means of transmitting light, electricity and magnetism, and we are looking forward to its properties explaining chemical actions and gravitation. We are still looking for a theory of its structure which will give a dynamical explanation of its properties. We know how to express these properties by quantities we call electric and magnetic force, whose laws we know, but whose laws we are, as yet, unable to explain by any structure working on dynamical principles. So far as we know, the properties of electric and magnetic force are explicable upon dynamical principles; so far there is no known necessity for seeking for adynamical properties in the ether; so far we may hope to explain electro-magnetism upon the dynamical principles of Newton's laws without invoking any other principles than those of force and inertia, as expounded in these laws. Until, however, a satisfactory theory of the nature of the ether has been actually invented, there will remain some doubt as to the adequacy of these fundamental dynamical laws to explain all its properties. The direction in which it is most probable that an explanation will be found is in the hypothesis that the ether is of the nature of a perfect liquid full of the most energetic motion. We know that a gas consists of separate molecules in intensely energetic irregular motion. I expect that the ether is a perfect liquid in intensely energetic irregular motion: much more rapid than that of any gas: with a rapidity of internal motion comparable with the speed of light: maybe with enough energy in each cubic centimetre to keep hundreds of horse-power going for a year, if only we could get at it. So far as this hypothesis has been worked at there seems nothing impossible about it, but, on the contrary, much possibility in it, and, to my mind, its inherent simplicity confers on it a great probability.

Be that as it may, we now know that in the electric lighting of our cities, in electric tramways and railways, in electric furnaces and electrolytic vats, and in the other innumerable applications of electricity, we are harnessing the all-pervading ether to the chariot of human progress, and using the thunderbolt of Jove to advance the material welfare of mankind.

Having thus shortly considered the progress of electrical science, the history of the *applications* of electricity may be thus summarised. Shortly after Œrsted discovered the magnetic effect of an electric current this discovery was applied to telegraphy, and Faraday's discovery of how to generate electric currents by magnetism was almost immediately applied to the same use. Telegraphy developed rapidly, and many subsequent discoveries were due to the observations made in the practical application of electricity to telegraphy. This has been developing ever since, accumulating knowledge and applying the accumulations to produce more knowledge and more applications, till all this has resulted in the perfection of the multiplex telegraph and the wonders of the telephone and wireless telegraphy. No other department of applied electricity has had such a continuous development, hardly any interval elapsing between discovery and application in its case, while in almost

[1] Inaugural address to the Dublin Section of the Institution of Electrical Engineers, delivered by Prof. G. F. Fitzgerald, F.R.S. Abridged from the *Journal* of the Institution, April.

every other case years have elapsed between discoveries and their application. It is especially the object of this address to call attention to the cause of this and to the lessons to be learnt from it.

Within the first decade of the century, electrolysis and the electric light were discovered; but, except on a small scale in electro-plating, it was reserved for the last quarter of the century to see their application to the general use of mankind. Before her Majesty began to reign, Faraday had discovered how to generate electric currents by magnetic actions; but, except to generate currents to light a couple of lighthouses, no applications of Faraday's discovery to generate electric currents on a large scale was made till Wilde, Gramme and Siemens worked at it, more than thirty years after its discovery. The application of electric currents to transmit power on a small scale was made in the electric telegraph years before any applications were made on a large scale. Except for a few experiments by Jacobi and others, the transmission of power by electric currents on a large scale is the work of the last twenty—one might almost say of the last ten—years.

Consider now what are the characteristics of the applications which developed continuously, and what were those of the applications which lay dormant for years. Maybe we can learn from this consideration how to arrange that, in the future, our discoveries may not lie for years dormant.

The most noticeable difference between the applications of electricity that developed and those that lay dormant is that those that developed were useful on a small scale, while those that lay dormant were not useful until developed on a large scale. Electro-plating and telegraphy were useful on quite a small scale. Experiments as to their efficiency could be conducted on the laboratory scale with quite cheap apparatus, and thus they were actually developed.

A recognised authority, who is fond of poking paradoxical fun at professors, has recently stated that "the progress of telegraphy and telephony owes nothing to the abstract scientific man." I do not know exactly what he means by the abstract scientific man, but I do know that telegraphy owes a great deal to Euclid and other pure geometers, to the Greek and Arabian mathematicians who invented our scale of numeration and algebra, to Galileo and Newton who founded dynamics, to Newton and Leibnitz who invented the calculus, to Volta who discovered the galvanic cell, to Œrsted who discovered the magnetic action of currents, to Ampère who found out the laws of their action, to Ohm who discovered the law of the resistance of wires, to Wheatstone, to Faraday, to Lord Kelvin, to Clerk Maxwell, to Hertz. Without the discoveries, inventions and theories of these abstract scientific men, telegraphy as it now is would be impossible.

We have seen that electro-plating and telegraphy were capable of development on a small scale, and were consequently largely developed by laboratory research. The development of dynamos from Faraday's discovery required expensive experiments, and to test their efficiency on a large scale required very expensive experiments indeed. It was not possible to conduct experiments that would be of much practical use on the small scale on which laboratory experiments have to be conducted, on account of the miserable pittance that is at the command of scientific laboratories. The only opportunity of conducting experiments on a large scale is when an inventor can control capital, as, for example, if he himself is in the position of an engineer to some wealthy body whose money he can employ on experiments. Jacobi and others spent a good deal of money, no doubt, on experiments in power distribution by electro-magnetic engines, but their expenditure, though quite considerable as compared with the usual run of laboratory experiments, was as nothing compared with the enormous sums spent by the pioneers of modern electro-magnetic machinery on *their* experiments.

What we have found, then, is that development depended on whether or no people experimented energetically upon how to render each discovery of practical utility; where experimenting was energetic, development was rapid; where experimenting was not energetic, development was slow. We have further found that the energy of experimenting depended on the money available; where little money was required, development was rapid; but it was slow where large sums of money were required in order to perform valuable experiments.

We may further inquire how it happened that money and time became available for costly experiments. Money is available for laboratory experiments by the beneficence of private and public endowment, and time is available by the devotion of scientific men to the advancement of natural knowledge. These have been available because some few men have had faith in the desirability of knowledge both for its own sake and for the material and moral advantage of mankind. Money has been available in England on a large scale in the past because of the enthusiastic faith of some very few men in the possibilities of scientific discoveries. One of the most remarkable instances of this faith was in the case of the great experiment of laying the Atlantic cable. A few men with strong faith impressed their belief on a few capitalists, and after years of most expensive experimental work they at last brought their great undertaking to a successful issue; the general body of capitalists meanwhile looking on with amused incredulity. The development of the dynamo depended similarly upon the strong faith of individuals, who spent immense sums of money and much time and energy on the subject because they had faith in its possibilities. It is remarkable how many of the developments of scientific discoveries of the latter years of the century have been due to foreigners or firms with foreign leaders, such as Siemens Brothers. This has been largely due to the fact that foreigners are far in advance of us over here in their faith in the possibility of using scientific discoveries. The rapid advance of the applications of science in the last quarter of this century has been very largely due to the growth of this faith. It has grown to a strong conviction in the ordinary public of America and the Continent, and is growing daily stronger over here, but is still far weaker here than in other parts of the civilised world. The result of this has been that while the germs of many of the greatest inventions have been made within the British Isles, we have not been pioneers in any great advance in the applications of electricity since the development of submarine telegraphy. Possibly another cause has been our obstinate retention of our abominable series—one cannot call it system—of weights and measures. It is with great hopefulness that I see public opinion gradually growing in favour of the metric system.

How does it happen that one of the foremost countries in advancing science has been one of the last to appreciate the possibilities of applied science? This has been due partly, no doubt, to our great success as manufacturers and as mere mechanical inventors. No doubt Watt was a truly scientific inventor, and even mere mechanical inventors are appliers of scientific knowledge that was discovered, in the most part, by scientific men centuries ago; but most of our success as manufacturers has been due to mechanical inventions and to our well-trained and expert artisans, and not to the useful application of recent scientific discoveries. This great success, and the absence of scientific training in our schools, and the want of contact between manufacturing and scientific society, have all contributed to prevent a due appreciation of the value of scientific discovery and experiment as a means of advancing the material wealth of society.

When can we expect the country or generous benefactors to learn that science on a large scale is at the basis of the material prosperity of the country, and that science on a large scale is very expensive. Of what use is 200*l.* a year in making experiments on a commercial scale? Ten thousand pounds a year would be more like the figure required; and 10,000*l.* a year could be most profitably spent on experimental work here in Ireland, on the one subject of utilising our bogs It is most probable that the energy of their combustion could be transmitted to our towns to provide them with light and power; but the preliminary experiments are far beyond the capabilities of a scientific laboratory.

Then there are the questions of three-wire tramways, leaky telegraph lines, submarine relays, sun engines, of flying machines which Lord Rayleigh considers can be constructed if money enough were forthcoming, and of vacuum tubes as a means of illumination, and of numberless other matters already ripe for application, to say nothing of the innumerable scientific discoveries that have not yet been even suggested as having practical applications.

Besides these industrial laboratories, all our Government departments, such as the army and navy, should have large experimental organisations where any invention that promised success would be developed and seriously tried. The decision of what to try should not be left to mere officials, however distinguished, but should be referred to independent scientific advisers—persons who were not trammelled by official traditions, but were in touch with scientific advance and enthusiastic believers in it. If the country spent a couple of millions per annum on experimental work of this kind it would bear much fruit, and we should not find ourselves out-shot by semi-barbarous farmers.

Hope is the great incentive to exertion. Without it a nation is dead. Without it we lose all belief in the possibility of improvement, and improvement at once becomes impossible. The history of electrical engineering, the utilisation of the all-pervading ether for the service of man, should strenghen our hope and our belief in the possibility of improvement. For has it not revolutionised society and enabled high and low, rich and poor, to lead better lives, by making life less hard and grimy, and thus improved the well-being of man both materially and, what is far more important, morally as well?

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—The following are the principal lectures announced for this term:—Prof. Clifton, practical physics: Mr. Baynes, elementary electricity and magnetism; Mr. Jervis-Smith, dynamo and motor machinery, with electrical testing; Prof. Odling, silicon compounds; Dr. Fisher, metals and organic chemistry; Mr. Watts, organic chemistry; Mr. Marsh, practice of organic chemistry; Mr. Hartridge, aromatic compounds; Mr. Vernon Harcourt, subjects of the preliminary examination; Mr. Elford, the elements treated in the periodic order; Mendeleef's periodic system, Groups vii. and viii.; great chemists and their work; Mr. Walden, synthetical methods in organic chemistry; Mr. Wilderman, equilibrium and velocity of physical and chemical reactions in heterogeneous systems; Prof. Miers, the new theories of crystal structure; Mr. Bowman, the crystallography of optically active substances; Prof. Sollas, history of the earth; Mr. Mackinder, the natural regions of the Old World; Mr. Dickson, the climatic regions of the globe; Mr. Herbertson, mountain types; Prof. Weldon, general course of morphology; variation, inheritance, and natural selection; Mr. Goodrich, annelids; Mr. Jenkinson, vertebrate embryology; Mr. Günther, arthropoda; Mr. Barclay Thompson, mammalian morphology; mammalian palæontology; Prof. Gotch, the central nervous system; Prof. Gotch and Mr. Ramsden, advanced course of physiology; Mr. Mann, advanced histology of nervous system; Mr. Burch, physiological physics; Mr. Mann, practical histology; Prof. Vines, elementary course of botany; Prof. Tylor, early stages of civilisation (arts of subsistence and protection); Sir J. Burdon Sanderson, general pathology; Dr. Ritchie, pathological bacteriology; Dr. Collier, medical diagnosis; Mr. Symonds, fractures and dislocations; Prof. Thomson, vascular and respiratory systems; Mr. Smith Jerome, medical pharmacology and materia medica; Prof. Esson, the synthetic geometry of conics; Prof. Love, hydrostatics and hydronamics; Prof. Elliot, the theory of functions.

Mr. William Hatchett Jackson, science tutor of Keble College, who has been elected to the post of Radcliffe's librarian, vacant by the resignation of Sir Henry Acland, has entered on his duties. The new Radcliffe Library, erected for the University by the Drapers' Company, is meanwhile approaching completion.

Scholarships in natural science are announced by the following colleges:—Merton and New, July 3; Balliol, Christ Church and Trinity, December 4; Magdalen, December 11.

It has been decided that diplomas in geography shall be granted by the University; the details of the scheme have yet to come before Congregation and Convocation.

CAMBRIDGE.—Honorary degrees are to be conferred on the Hon. Edmund Barton, delegate from New South Wales in connection with the Australian Commonwealth Bill, and on H.M. the King of Sweden and Norway.

There are vacancies at the University Tables in the Zoological Stations of Naples and Plymouth. Applicants should write to Prof. Newton before May 24.

It is proposed to affiliate the University of Tasmania. Bachelors of Arts and Bachelors of Science of that University will thereby be entitled to proceed to Cambridge degrees after two years' residence.

The Financial Board estimate that, owing to the loss of fees, &c., consequent on the absence of many members of the University in South Africa, the income of the Chest will next year fall short of the necessary expenditure by 650*l*.

Seventeen additional freshmen were matriculated on May 5.

Mr. Thomas Andrews, F.R.S., has presented to the Chemical Laboratory a valuable echelon spectroscope, for which the special thanks of the University have been ordered.

DR. TUNNICLIFFE has been appointed to the chair of materia medica and pharmacology in King's College, London.

DR. JOHN WYLLIE has been elected to succeed the late Sir Thomas Grainger Stewart in the chair of medicine in the University of Edinburgh.

IN order to enable Essex dairy-farmers, and ladies engaged in dairy-work, to gain an insight into the organisation and practice of the agricultural industries of Denmark, the Essex Technical Institution Committee have made arrangements for a party to visit that country. Visits will be made to a number of schools and other institutions, farms, and manufactories concerned with dairying, and a valuable insight will be obtained into Danish methods. Full particulars of the programme can be obtained from Mr. T. S. Dymond, County Technical Laboratories, Chelmsford.

THE growth of municipal technical schools in England during the ten years which followed the passing of the Technical Institution Act, 1889, formed the subject of an inquiry made by the National Association for the Promotion of Technical and Secondary Education a short time ago. The results showed that a capital sum of 2,340,651*l* had been spent on technical schools, and that there were 239 such schools (including agricultural and dairy schools and domestic science schools) in existence or in course of establishment. Since the conclusion of the inquiry, technical schools had been erected, or it had been decided to erect them, in several other towns, and the latest report shows that the total amount incurred for 272 schools under municipal and public bodies is now at least 2,643,172*l*.

THE progress of science and education in the United States is largely due to the interest taken in the work of colleges and universities by private benefactors. Scarcely a week passes without affording instances of generous gifts to institutions of this kind, by persons who desire to promote the development of national character and industries. As an example of this public spirit, we have the case of Dr. D. K. Pearson, of Chicago, who, on attaining his eightieth birthday recently, decided to add 525,000 dollars to the 2,000,000 dollars he had previously given to colleges. Then we have the announcement in *Science* that Mr. Andrew Carnegie has promised the trustees of the Carnegie Institute, Pittsburg, Pa., to become responsible for 3,000,000 dollars, the amount estimated as necessary for the proposed extension and enlargement of the building at the entrance of Schenley Park. The new building will be nearly six times as large as the present one. We should be glad to be able to record many similar gifts to institutions devoted to science and education in this country.

ONE of the good effects of the technical education movement during the past ten years is that many secondary schools, such as grammar and endowed schools, which formerly excluded science from their curricula, have had to adapt themselves to modern requirements as a condition of receiving assistance from technical education authorities. The annual report of the National Association for the promotion of Technical and Secondary Education refers to an inquiry undertaken to determine the extent of the changes which have been brought about in this way, both by the establishment of new secondary schools and by the adaptation of existing secondary schools for the purposes of technical education. The facts revealed by the inquiry go to show that in England alone, since 1889, 81 new public secondary schools have been established, while 215 existing schools have been extended mainly for the purposes of science teaching. As regards the schools in the latter category, the extensions to 195 of them have resulted in the addition of 251 physical and chemical laboratories, 77 workshops for manual training, 76 lecture-rooms, and 50 class-rooms. The total sum of money involved by these developments is 764,449*l*. By their capital grants to secondary schools, County Councils have exerted a direct influence in the reorganisation, and have secured a voice in the management and control of the schools. By the Councils' annual maintenance grants, the work of reorganisation has been gradually consolidated, and the permanence of proper management and control has become assured. It is not surprising, therefore, that the latter, as a continuous source of income to secondary schools, have been increasing in number and in value during recent years.